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NEW ELECTRONIC INSTRUMENTATION IN DENTISTRY

**An Evaluation of Miniature Cardiovascular and Psychogalvanic
Skin Response Monitoring Devices**

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FOREWORD

This report was prepared in the Dental Sciences Division under Task No. 775303. It was submitted for publication on 3 November 1964. The time of the experiment extended from November 1963 to December 1964.

This report has been reviewed and is approved.

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ABSTRACT

The two instruments evaluated in this clinical study of over 200 patients have been employed and found to be potential aids to the practice of dentistry, establishing better rapport and presenting considerably more information on the physiologic activity of the patient than is routinely available. These instruments did not come between the doctor and his patients; on the contrary, they assisted the doctor in gaining more empathy for the patients, which is essential to successful treatment.

NEW ELECTRONIC INSTRUMENTATION IN DENTISTRY

An Evaluation of Miniature Cardiovascular and Psychogalvanic Skin Response Monitoring Devices

1. INTRODUCTION

The physician or dentist is necessarily concerned with his patient's reactions to environmental conditions and to stress directly or indirectly related to treatment. The appraisal of these reactions is difficult largely because of two factors: (1) The information sought is more subtle than that which a clinician seeks physically through careful inspection and observation, palpation, and auscultation. (2) The technic involves the personal equation to a critical degree. It may be said that the personal interaction between the doctor and his patient is one of extreme sensitivity.

Good rapport between doctor and patient, in the past, depended largely on the doctor's observation of many cardinal symptoms. It included sympathetic understanding and the use of many technics for diagnosis and treatment. Recently, however, new instruments that make use of the electron have been developed specifically for use in the fields of medicine and dentistry. Two such instruments have been clinically evaluated on more than 200 dental patients for possible use in dental treatment—(1) a transistorized psychogalvanometer and (2) a transistorized photoelectric plethysmograph transducer and bridge amplifier—both with audible readout.

2. THE PSYCHOGALVANOMETER

A transistorized psychogalvanometer indicates significant changes in skin resistance

as a corollary readout of the activity of the autonomic nervous system. When the instrument is coupled with a small transistorized amplifier and speaker, it converts any electrical signal into a frequency modulated sonic note for aural monitoring. Therefore, the instrument emits a changing tone as a continuous audible indication of patient autonomic responses during routine restorative or surgical procedures. It makes use of the psychogalvanic reflex to provide the doctor with a qualitative indication of patient stress. This then serves as a guide to his technic, or his treatment procedures, without his having to glance away from the patient to view a meter or read a graphic recording after treatment.

Measurement of the galvanic skin responses

The psychogalvanometer is essentially an instrument which measures the change in electrical resistance of the skin. A sudden drop in resistance between two areas of the skin, following exposure to a stressful situation, is a sensitive indicator of the sympathetic nervous system response to anticipation, anxiety, fear, threat, and true pain (1, 2, 3). The change in skin resistance occurs as a result of autonomic activity which has been demonstrated to be generalized—not merely localized (4, 5). The peculiarity of sweating on the palms, fingertips, soles, and in the axillae has been firmly established as being related to psychologic and sensory processes rather than to body temperature regulation (6, 7). Interestingly enough, arguments have also been advanced for the specific value of sweating in



FIGURE 1

Fingertip electrode of monel for obtaining electrical condition in measurement of resistance changes of the skin.

these areas as part of the mechanism of preparedness in terms of greater surety of grip (8, 9).

The electrodes are slipped on two alternate fingers of either hand and stabilized by simple spring-loaded clamps (fig. 1). These adjust readily to varying sizes of fingers. Alternate fingers are employed to minimize shorting of electrodes which could occur if adjacent fingers were used (fig. 2). No electrolytic paste is required; positive electrical conduction is established rapidly by the formation of salts between the skin and monel-metal electrodes. A single-finger electrode, gold plated and fashioned from phosphor bronze, was satisfactory in most cases. It contacted the volar surface of the fingertip pad as one electrode and the dorsal surface as the other. Individuals with heavily calloused fingers, however, required the use of the dual-finger electrodes.

After the use and purpose of the machine were properly introduced and explained to patients, they were relieved of the fear of an electric shock. Then, after a demonstration, all patients were very co-operative and, in fact, enthusiastic. Many expressed gratitude that such an instrument was to be employed that would truly indicate the gamut of emotions from anticipation to true pain.



FIGURE 2

Position of electrode on fingertips.

Procedure

After the patient is seated and made comfortable, the doctor shows him the instrument and asks his permission to attach the electrodes. The instrument is turned on by the sensitivity control (fig. 3) and is set approximately midway between 3 and 4. After a 10- to 15-second delay for adequate electrical contact to occur through buildup of sufficient ions, the instrument is adjusted for baseline.

A baseline determination and adjustment is made by eliciting the palmar reflex which creates an autonomic response and a corresponding drop in resistance, indicated by a deflection of the needle to the right and a simultaneous rise in frequency (not amplitude) of the audible signal. A very labile individual has a continuously variable change in resistance, which in turn causes the needle to fluctuate and the tone to constantly change in frequency. Baseline for the individual is adjusted by reducing the sensitivity control (fig. 3) until the needle remains at zero and then adjusting the trigger control until the tone just disappears. At this point, any stimulus stronger than the patient's adjusted baseline will cause the tone to appear and rise in frequency. It may thereafter be necessary to reduce further sensitivity should he react to

relatively innocuous stimulation such as might occur when the light is turned on in preparation for treatment.

As the treatment continues, the instrument will audibly indicate the patient's unconscious reaction to stress. Reaction is generally proportional to the threat, and all such emotions, including reaction to pain, will be indicated by the presence of the audible signal. Time of reaction will vary from individual to individual; appearance of tone indicating a drop in resistance requires from 0.5 to 2.0 seconds. A frank pain such as is elicited by a sharp pinch on the back of the hand usually, but not always, brings about an audible indication before anticipation of pain or a response to brushing the fingertip across the palm. As the operator becomes familiar with the instrument, he learns how to adjust and interpret the signal for the purpose of guiding his treatment procedures.

Typical case—the P. G. S. R. in oral surgery

A 25-year-old male required the surgical removal of an impacted lower third molar. He

was labile, having strong memories of a traumatic episode in which the other third molar had been extracted; bone had been removed and the crown split with chisels. His baseline was adjusted so that there was no audible indication of anxiety. A topical obtundent was applied, and 2 minutes later the block anesthetic was administered. The audible tone appeared and rose in frequency when the patient realized that he was to be injected. It then returned to baseline (off), rose again when the patient felt the pressure of the needle and anesthetic fluid, and then returned to normal baseline during the injection. The tone remained off while the patient was awaiting anesthesia. Pressure with an explorer on the anesthetized side gave no indication of pain; an equal amount of pressure in the same area on the opposite side caused a typical pain response.

The patient showed no indication of pain nor anticipation of it when the tissues overlying the tooth and bone were incised and retracted. There was a sudden indication of

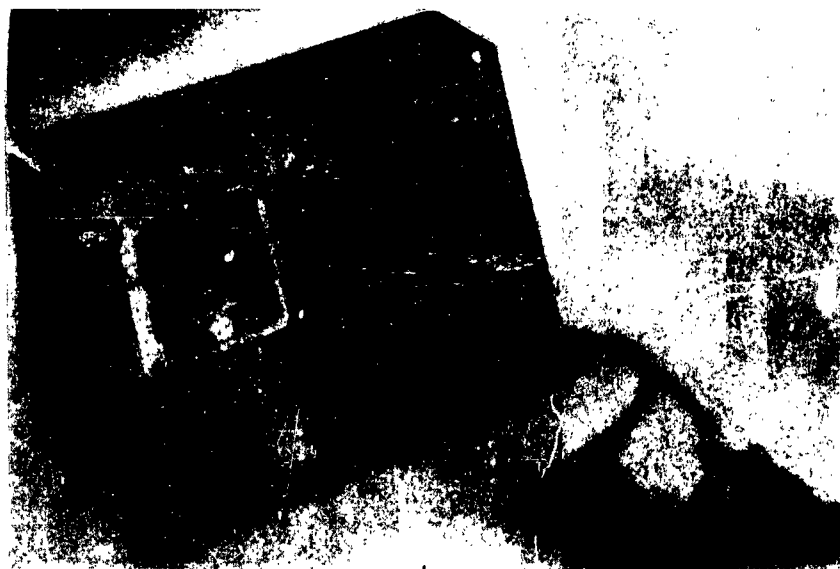


FIGURE 3

Front panel of psychogalvanometer. Meter indicates relative changes in resistance; speaker at right provides indication of resistance changes by alteration of tone frequency.

stress when the air turbine and vacuum tip were brought to the area; then, there was a return to normal even when the bone was being removed. Elevation of the tooth produced no stress—i.e., the tone remained off and the needle remained steady. As the tooth was being removed, there was a sudden indication of stress. The operator immediately asked the patient if he felt pain; the patient pointed to the vacuum tip and said that it was pinching his lips against his upper teeth.

The case described indicates the value of this type of readout. It permits information that otherwise might not become obvious to the operator. This then serves to establish better rapport. The patient mentally agrees to accept a certain amount of pain and discomfort. This level of acceptance may well be below the line of demarcation, above which there will be obvious outward manifestations of pain or discomfort. The patient is at times unnecessarily stressed because there is no outward indication of his discomfort. The use of the psychogalvanometer permits the doctor to detect, at a much lower level, the existence of stress, and, therefore, act accordingly.

There are many instances when the patient indicates pain or discomfort during a procedure only to have these indications (tensing, rapid inspiration of breath, jerking, or vocalizing) interpreted as anticipation or fright when the patient is actually experiencing a true pain. It is occasionally impossible to have all outward indications of complete anesthesia, when actually a few fibers are still conducting. It is extremely difficult at times to differentiate between this condition and complete anesthesia. By use of the psychogalvanometer, however, the differentiation can be more acute. The reaction to anticipation will be less than the reaction to true pain.

Hardy et al. (10) found the threshold of pain sensation to be remarkably constant in the same individual from day to day. Furthermore, the pain threshold, as measured in several hundred individuals, was of this same constancy regardless of age, sex, and experience. Statements regarding pain, however,

varied from, "I can take any amount of it" to "I am exquisitely sensitive to pain."

These facts all point to the inference that, whereas the threshold for the sensation of pain is uniform for most individuals, reactions to pain and threatening experiences vary greatly. These reactions constitute the most apparent aspects of a distressing experience, but frequently may not truly indicate the differentiation so necessary for empathy and guidance of treatment.

The small, self-contained, relatively inexpensive instrument investigated in this clinical study appears to be ideally suited for a more complete rapport between the doctor and his patient.

3. THE PHOTOELECTRIC PLETHYSMOGRAPH

The miniaturized photoelectric plethysmograph transducer and bridge amplifier is transistorized, compact, and self-powered. It senses and indicates peripheral cardiovascular pulse-pressure wave changes. When this is coupled with a sonic note, aural monitoring of the pulse rate, systolic-diastolic differentiation, and relative blood-pressure changes may be monitored during oral surgical or anesthesia procedures.

Monitoring the cardiovascular pulse-pressure wave

Plethysmographs are instruments designed to record changes in blood volume of limbs or segments of limbs. A common technic is to employ a rigid-walled chamber in which the limb is inclosed with a seal to maintain the space around the limb as a closed cavity. This cavity is completely occupied by fluid (air or water), and changes in volume are recorded by means of a float chamber connected to this device. A sensitive type of digital plethysmograph, devised by Goetz (11), follows the volume pulsation of the finger; recording showed a wave form closely similar to that of the arterial pulse at the wrist.

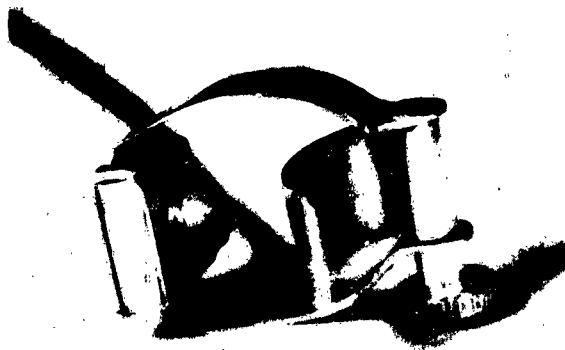


FIGURE 4

Fingertip attachment of photoelectric plethysmograph is by adjustable clamp.

Most of these instruments are bulky, require constant supervision, and are not suited to routine use in clinical practice.

An entirely different principle has been devised, employing a "grain-of-wheat" electric lamp which illuminates the capillary bed. Changes in absorption of light, as affected by the blood volume, which varies with the cardiovascular pulse wave, are sensed by a semiconductor diode-type photocell. A simple clamp mechanism (fig. 4) holds the photocell in close contact and next to the light source. In this manner, the instrument can detect not only the pulse rate, but also changes in blood flow which are dependent on the relative blood pressure in the form of a tone, which is modulated by the pulse-pressure wave. A distinct pulse is heard. A change in frequency can audibly distinguish changes in flow superimposed on an overall change in frequency as caused by volume (pressure) alternations.

Procedure

The plethysmograph is attached to any finger (fig. 5) and the patient is reminded to relax the hand at a comfortable rest position on the chair. The hand is naturally at rest when a general anesthetic has been administered; however, when the patient is conscious, movement will cause changes in flow which

will be artificial in that the change in blood flow would not be due to physiologic variations.

The instrument is turned on by means of the sensitivity control (fig. 6) and set initially to approximately 5. The balance control *B* is rotated clockwise to 10, then counterclockwise until the tone is produced. Slight changes within this area will alter the tone for a pleasing effect. This also selects the range of pressure changes available. Increasing the sensitivity control *A* will give greater sensitivity; however, the balance control *B* will require readjustment until a distinction in tone permits differentiation of anacrotic and diacrotic pulse superimposed over the tone of the overall pressure. The instrument setting is checked by raising the hand that is attached to the plethysmograph. At that point a lowering in frequency will indicate a drop in blood flow in the fingertip. The transducer should be shielded from direct light, since exposure to light produces an electrical signal from the photocell which interferes with the clarity of the pickup of the light changes within the finger. Particularly destructive to the signal clarity is the light from fluorescent fixtures which produce an audible hum. To eliminate the problem of light falling directly on the finger, an effective filter was made by placing gauze (4 by 4 inches) over the finger.

Typical case—general restorative

A 40-year-old male was seated for routine restorative dentistry. The doctor obtained



FIGURE 5

Position of plethysmograph on finger of patient.



FIGURE 6

Front panel of peripheral cardiovascular monitor. Miniature speaker provides audible signal of digital pulse-pressure activity. Outlets to recorders, oscilloscopes, and earphones, if desired, are on rear panel.

permission to place the plethysmograph and explained the function and use of the instrument. The patient appeared labile; his hands were moist; his motions were somewhat jerky; and he laughed nervously. When he was asked how he felt, he said that he was apprehensive and had postponed treatment of a fractured bicuspid buccal cusp for over six months because he could not stand to have his teeth drilled. He further stated that he had decided to have the work done because the sharp edges of the fractured tooth were cutting his cheek and that he was afraid of cancer.

The tone from the instrument very clearly indicated an arrhythmia with an occasional dropped systole. After the patient was questioned further, he disclosed that he had slept less than three hours. Therefore, treatment was not indicated at the time (12), and because of the cardiac arrhythmia, the patient was referred to his physician for a thorough examination. Probanthene (15 mg.) was prescribed one-half hour before a subsequent dental appointment, and the treatment was completed without incident. The heart

rate was regular with no more than a slight tachycardia immediately following administration of a block anesthetic.

4. DISCUSSION

Generally, the dentist is not prepared to interpret accurately the audible signal of the cardiovascular pulse-pressure wave as presented by this instrument, nor in fact, with more extensive instrumentation. Moreover, he would be unwise to attempt to do so, but he can be informed of gross changes or abnormalities of the cardiovascular system. Tachycardia, dropped or extra systoles, sudden changes in frequency of the base tone, indicating a rise or fall of blood pressure, are all indications for caution in treatment. The dentist is unaware of these indications with the usual armamentarium. With this instrument, however, he is able to constantly monitor the pulse with relative pressure changes without glancing away from his work. A very great number of cases involving oral surgery are being accomplished, particularly under general anesthesia,

in which no monitoring of cardiovascular activity is accomplished during administration of the anesthetic or during the operation. There is little doubt that the incident of cardiac arrest may be considerably higher than has been reported because of the vast number of cases in which no monitoring of pulse rate or blood pressure was performed.

Operation of the instruments is uncomplicated, and patients do not object to having the electrodes fitted to their fingers. The tone is at times annoying to the operator, but this may be rectified by turning the balance control of the photoelectric plethysmograph counterclockwise to a lower audible frequency until it becomes comfortable to the ear. The trigger control on the psychogalvanometer can be adjusted to a point where the note is not heard; however, when there is a response to stress or pain, the frequency change becomes audible.

To be aware of the emotional reaction of the patient during clinical procedures and to monitor audibly gross changes in pulse pressure are primary considerations for proper treatment. The instruments evaluated in this study are *not* measuring devices. They are

inadequate for research purposes unless they are utilized in combination with recording and measuring devices.

The psychogalvanometer in general is no more than a fairly adequate indicator of a change of direction of mental activity; in no sense is it an adequate or direct measure of change (5). Changes, however, are significant, because they are related to the autonomic response of the patient.

The photoelectric plethysmograph, when employed on the finger, can readily indicate pulsatile flow which, however, can be altered by conditions other than those of cardiac origin, such as peripheral vasoconstriction noted in certain individuals when stressed. Such vasoconstriction would reduce the volume of blood within the fingertip and thus produce a lowering of the frequency of the audible tone. This would be interpreted to mean that a drop in blood pressure has occurred when, actually, the pressure may have risen. Such changes or variations in pressure are, nevertheless, not otherwise noted unless such an instrument is in use. The value of the instrument as a monitoring device, therefore, continues to be paramount.

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